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19. Late Quaternary Productivity Fluctuations off Angola: Evidence from Benthic Foraminifers, Site 1079[1]

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ABSTRACT

Benthic foraminifer accumulation rates (BFAR) >150 µm and species composition were used to reconstruct the late Quaternary productivity in the Mid-Angola Basin at Ocean Drilling Program Site 1079. In general, BFAR values indicate higher productivity during glacial periods than during interglacials. Spectral analysis of the BFAR record shows that benthic foraminifers were sensitive to climate forcing at 100- and 23-k.y. periodicities. These results are similar to those observed in nearby regions, as described by the Geo-Bremen group. The benthic foraminiferal fauna is dominated by low oxygen–tolerant infaunal species, with *Bolivina pseudopunctata* and *Bolivina dilatata* as the most abundant species. *B. pseudopunctata* appears to be well correlated with marine organic carbon (C_{org}), whereas *B. dilatata* tends to increase when the influx of terrigenous organic matter dominates the environment. Furthermore, the spikiness in the abundance of *B. pseudopunctata* suggests that this species may be opportunistic and may respond to threshold values in environmental conditions.

INTRODUCTION

A central aim of the drilling strategy of Ocean Drilling Program (ODP) Leg 175 was to obtain records for the reconstruction of productivity along the western African margin between the Congo and the Cape (Wefer, Berger, Richter, et al., 1998). A National Aeronautics and Space Administration (NASA) compilation of satellite-derived pigment

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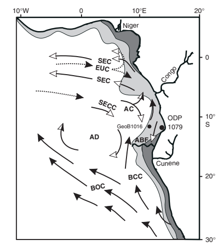
distributions (Berger and Wefer, 1996, fig. 4) shows high productivity all along this margin, with a distinct minimum off the shores of the Angola Bight. The annual offshore temperature here is ~23°C, and the latitudinal anomaly is modest (~1°C), reflecting subdued upwelling activity. The nutrient content of subsurface waters, on the other hand, seems normal or on the high side of the range (phosphate and silicate at 100 m depth, compiled by Joseph L. Reid, as contoured in Herzfeld and Berger, 1993; see fig. 27 in Berger et al., 1998). This environment of subdued upwelling, then, embedded within much stronger upwelling activity to the north and south, was the target of Site 1079 (Fig. F1), for which we present a first attempt at reconstructing late Quaternary productivity using benthic foraminifers.

The length of the record is ~230 k.y., as reconstructed from oxygen isotope stratigraphy.

We compare our results with records from the continental margin off Angola (core GeoB1016; 11°46.2′S, 11°40.9′E; water depth = 3411 m), recovered on a cruise of the *Meteor* (Wefer et al., 1988). Our results are consistent with earlier studies in nearby regions (Schneider et al., 1996, 1997; Wefer et al., 1996) and over much of the low-latitude ocean (Berger et al., 1994), showing stronger upwelling during glacials. However, the transitional position of the area studied, as a minimum between two high-productivity regions, gives rise to more complicated patterns, presumably as a result of alternating expansions of the adjacent upwelling areas. These patterns of productivity are also reflected in changes in abundance and species composition of benthic foraminifers at Site 1079.

F1. Location of Site 1079 and core GeoB1016, p. 13.



GEOGRAPHIC SETTING

Site 1079 was drilled outside the Angola Bight on the upper continental slope during Leg 175 (Wefer, Berger, Richter, et al., 1998); it is located in the eastern Mid-Angola Basin (11°55.78′S, 13°18.54′E; water depth = 749 m) (Fig. F1). Upwelling here is seasonal and strongly related to the Angola Thermal Dome (AD), which pumps cold nutrient-rich waters upward (denoted by cyclonic surface circulation off Angola in Fig. F1). The dome forms as a result of the interaction between the Benguela ocean current (BOC) (Fig. F1) and the South Equatorial Counter Current (SECC). A river plume (and associated estuarine pumping) in combination with eastern equatorial upwelling generates high productivity off the Congo, and the three fields (dome, river plume, and upwelling) are thought to merge in the sedimentary record. Productivity in the surface waters off the Angola Bight is somewhat lower than in the adjacent upwelling areas to the north and south, according to satellite information and based on previous geologic studies (Berger and Wefer, 1996; Shipboard Scientific Party, 1998a), which would put both core GeoB1016 and Site 1079 into a region of reduced production. The site was drilled to obtain information on Angola margin sedimentation where it is neither influenced by riverine input nor sustained coastal upwelling activity. Penetration was limited for safety reasons; recovery of sediments was through advanced piston coring (maximum penetration = 128.3 mbsf).

At present, the Angola-Benguela Front (ABF) (Fig. F1) is located south of Site 1079. For most of the past 200 k.y., this region of increased production may have been much closer to Site 1079 or may have even moved across its latitude toward a more northerly position (Jansen et al., 1996). These apparent movements of the ABF display a periodicity somewhere near 30 k.y. (fig. 4 of Jansen et al., 1996). Jansen et al. (1996) used spectral analysis to identify a strong 15-k.y. signal, which they relate to the sum frequency of the 23- and 41-k.y. cycles. One task in reconstructing the productivity of Site 1079 is to check the possibility that migrations of the front across the site resulted in cyclic productivity compatible with the periods identified by Jansen et al. (1996).

MATERIALS AND METHODS

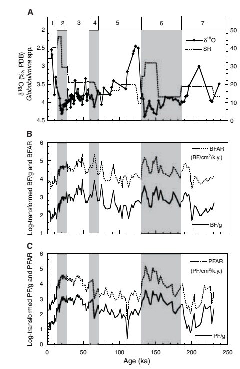
The sediments at Site 1079 consist of uniform olive-gray silty clays with varying amounts of nannofossils and foraminifers. In contrast, diatoms, silicoflagellates, and radiolarians are absent. The content of organic matter averages 3 wt%, which is high for ocean margin areas. We examined samples from Hole 1079A. The sampling spacing was 20 cm from 0 to 16.45 mbsf and 40 cm from 16.45 to 47.05 mbsf. Since Deep Sea Drilling Project (DSDP) Leg 94 (Ruddiman, et al., 1987), researchers have reported coring gaps between successive advanced hydraulic piston corer cores, ranging from 0.5 to 2.7 m (Ruddiman, Sarnthein, Baldauf, et al., 1988; Farrell and Janecek, 1991; Hagelberg et al., 1995). Hence, it is reasonable to consider that there might be gaps between cores. To obtain a better estimate for depth below seafloor for each sample, we assumed a gap size of 0.6 m and assigned a new depth to each sample. The coring gap was deduced by visual comparison of magnetic susceptibility and digital color reflectance data for Holes 1079A, 1079B, and 1079C (Shipboard Scientific Party, 1998b). Approximately 15 cm^3 of each sample (N = 150) was freeze-dried, soaked in a Calgon solution overnight, and then washed over a 63-µm mesh sieve. The coarse fraction was dry sieved over a >150-µm mesh sieve, and in most cases, samples were split using an Otto microsplitter. Between 70 and 2000 (mean = 380) benthic foraminifers were counted from the >150-µm fraction. The >150-µm size fraction has been used extensively for paleoceanographic studies and for many studies of living foraminiferal distributions in the South Atlantic (e.g., Mackensen et al., 1995; Schmiedl, 1995). Thus, it is convenient to use the >150-µm size fraction to make direct comparisons between studies. However, examining only the larger size fraction may result in a significant loss of information, especially in intense upwelling areas and low-oxygen environments (e.g., Sen Gupta et al., 1987; Sen Gupta and Machain-Castillo, 1993). According to growth experiments, foraminiferal species mature faster with more available food (e.g., Bradshaw, 1961), but it is not clear that adult test sizes are always smaller as a result (Pedersen et al., 1988). Also, specimens in the 63- to 150-µm size fraction are more susceptible to post-depositional destruction (e.g., Rathburn and Miao, 1995).

To make our data set comparable to previous studies on living benthic foraminifers in the South Atlantic Ocean, we followed the taxonomic concepts of Mackensen et al. (1990, 1993) and Schmiedl (1995). Planktonic foraminifers and planktonic foraminiferal fragments were also counted in the same set of samples. In several samples where benthic foraminifers abundances were either very high or low, planktonic foraminifers were also identified. The relative abundance of *Globigerina bulloides* was used as an additional tool to recognize variations in productivity.

Organic carbon (C_{org}) was determined as the difference between total carbon concentrations measured by a Perkin Elmer 2400 CHN elemental analyzer (Verardo et al., 1990) and the carbonate carbon concentrations measured by a Coulometrics inorganic carbon analyzer (Engleman et al., 1985). Repeated measurements of various samples indicate that the analytical precision is ±0.87% for total carbon and ±3.3% for $CaCO_3$.

Isotopic determinations were carried out at the Stable Isotope Laboratory of Scripps Institution of Oceanography using a Carousel-48 automatic carbonate preparation device coupled to a Finnigan MAT252 mass spectrometer. The long-term precision of the standard NBS-19 over the period of a year is better than 0.1‰ for the $\delta^{18}O$.

The age model (Fig. F2A) was derived from the $\delta^{18}O$ record of *Globobulimina* spp., using the age assignments of Imbrie et al. (1984). These assignments are employed here for the sake of comparison with other late Quaternary records tied to the SPECMAP scale, although they are too young for both Termination I and Termination II (by 2–6 k.y.) (Berger et al., 1996). The benthic and planktonic foraminiferal accumulation rates (BFAR and PFAR) were calculated from the product of the sedimentation rates (in centimeters per thousand years), the dry bulk density (in grams per cubic centimeter), and the number of benthic and planktonic foraminifers per gram of dry sediment (in number of benthic foraminifers per gram [BF/g] and number of planktonic foraminifers per gram [PF/g]), respectively. In this study, we used BFAR as a paleoproductivity proxy (Herguera and Berger, 1991; Herguera, 1992). This method is based on the hypothesis that the number of benthic foraminifers per unit area and unit time depends on the supply of organic carbon to the seafloor. Sedimentation rates, ranging from 5 to 50 cm/k.y., were determined by linear interpolation between age control points (Fig. F2A). Dry bulk density values were interpolated from shipboard physical properties data for Site 1079 (Wefer, Berger, Richter, et al., 1998). The benthic and planktonic foraminiferal abundances vary over large ranges; some values are very small, whereas some are very large. We transformed the scale to logarithms to base 10 to enable all the data to be properly viewed.



F2. Age scale and productivity estimates, p. 14.

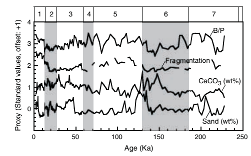
Patterns of species association were explored through cluster analysis of the relative abundance of species with >5% in at least five samples. Clusters were based on the correlation matrix (distance metric is 1-Pearson correlation coefficient), using average-linkage clustering (SYSTAT). Spectral analyses of the number of benthic foraminifers per gram and BFAR records were performed using the software program described in Schulz and Stattegger (1997).

RESULTS AND DISCUSSION

The $\delta^{18}O$ record reproduces well the contrast between Stages 2 and 1, and between Stages 6 and 5 (Fig. F2A). Stage 4 is not well represented in our data. Not enough isotope determinations are available for Stage 7 to define this period. Comparisons of the *Globobulimina* spp. $\delta^{18}O$ record with the BFAR and PFAR indices reveal higher accumulation rates of foraminifers during glacial periods. Transitions of BFAR and PFAR between glacial and interglacial regimes are rapid. Furthermore, foraminiferal abundance maxima tend to occur during the transitions. The original abundance index (BF/g and PF/g) shows very similar patterns (Fig. F2B, F2C). The close correspondence of these parameters indicates that BFAR and PFAR records are not an artifact of sedimentation rate estimates.

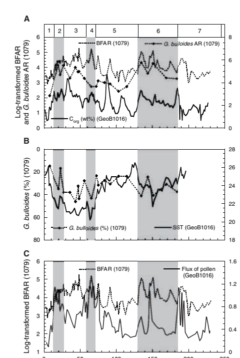
The benthic foraminiferal assemblages represent an integration of foraminiferal shell production and preservation in the seafloor, and a portion of the variability in benthic foraminifers abundance may well have to be ascribed to fluctuations in preservation. Several methods can be used to assess the state of preservation, such as (1) percentage of $CaCO_3$ (e.g., Luz and Shackleton, 1975), (2) percentage of sand fraction (>63 µm) (e.g., Johnson et al., 1977), (3) percentage of fragmented planktonic foraminifer tests (fragmentation) (e.g., Thunell, 1976), and (4) ratio of benthic to planktonic foraminifers (B/P) (e.g., Parker and Berger, 1971). Because each of these approaches may partly be controlled by other factors (e.g., productivity, dilution, and ecology), we look at them jointly (Fig. F3). The carbonate and sand content do not correlate well with BF/g (r = 0.45 and r = 0.31, respectively), as might be expected if preservation were the controlling factor for all three series. On the other hand, the overall trends in B/P and fragmentation point to increased dissolution during interglacials, with better preservation during glacial periods. Gaps in the fragmentation record (mostly during isotopic Stages 5 and 7) represent intervals with very few planktonic foraminifers and planktonic foraminifer fragments. We attribute the lack of planktonic foraminifers and fragments not to dilution but dissolution, because the sedimentation rate was not particularly high during those intervals. Nonetheless, benthic foraminiferal tests are generally in good condition and do not show a high degree of fragmentation. Consequently, although a preservational effect is likely, the evidence suggests that productivity is the dominant factor in producing the BF/g record.

F3. Comparison of preservation-related indices, p. 15.



To further test that the benthic foraminifers at Site 1079 are responding to productivity fluctuations, we compare the BFAR record with independent evidence of variations in productivity. The planktonic foraminifer *G. bulloides* is known to favor nutrient-rich upwelling areas in the tropical ocean (Prell and Curry, 1981). It also occurs in the coastal upwelling area off Namibia (Giraudeau, 1993) and in the eastern equatorial upwelling region (Kemle-von Mücke and Oberhänsli, 1999). Although only a few samples were analyzed for their abundance in planktonic foraminifers, it seems that increased abundances of *G. bulloides* are consistent with the idea that productivity was high during glacial intervals and low during interglacials (Fig. F4A). Moreover, its relative abundance shows a pattern similar to that of sea-surface temperature (SST) (Fig. F4B), based on alkenone analyses in core GeoB1016 (Schneider et al., 1995). Of course, *G. bulloides* is not a particularly dissolution-resistant species, and it could be argued that reduced abundances during interglacials result from dissolution.

F4. Upwelling indices, p. 16.



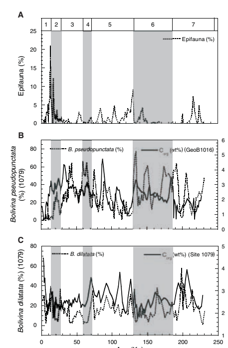
We also compare the BFAR record with the C_{org} (in weight percent) record in core GeoB1016 (Fig. F4A). Given the strong variations and relatively high pollen content (Ning and Dupont, 1997), we cannot exclude varying terrigenous portions of C_{org} in core GeoB1016. However, we believe C_{org} (weight percent) in core GeoB1016 is a better indicator for marine productivity than that of Site 1079, more strongly influenced by the presence of continental-derived material (Shipboard Scientific Party, 1998b). We use the percentage of C_{org}, instead of the accumulation rate (C_{org} AR), because it has been shown that in core GeoB1016 the record of C_{org} concentration is more consistent with records of nutrient proxies than the C_{org} AR (Schneider et al., 1994), probably biased by problems with the oxygen isotope stratigraphy (Bickert, 1992). Despite a few mismatches, the records of C_{org} (weight percent) and BFAR show a similar temporal variability. It is been suggested that BFAR may not generally be used as a productivity tracer.

Naidu and Malmgren (1995) showed that BFAR did not record the productivity signal in the upwelling and oxygen minimum zone along the Oman Margin. They argued that the low oxygen concentrations might instead be controlling the benthic foraminifer abundance. Our data suggest that, similar to the results of Guichard et al. (1997) off northwest Africa, at Site 1079 oxygen was not a limiting factor, and the benthic foraminifers responded primarily to changes in the flux of organic matter.

There is also a good correlation between the BFAR record and the influx of pollen and spores measured in core GeoB1016-3 (Ning and Dupont, 1997) (Fig. F4C). If we interpret the pollen flux as a measure of offshore winds (Ning and Dupont, 1997), the relationship suggests that during glacial periods enhanced winds increased the upwelling of cold and nutrient-rich waters, supporting high productivity levels.

Additional clues on the course of productivity variations can be obtained from the changes in composition of the benthic foraminifer assemblage. Loubere et al. (1993) and Loubere (1996) showed that the link of taphonomic process to organic carbon flux, combined with benthic response to organic flux, produces distinctive fossil assemblages linked to carbon flux gradients. At Site 1079, the assemblage is dominated by calcareous taxa with infaunal microhabitat preferences and ability to tolerate persistent oxygen depletion resulting from the oxidation of organic matter. In contrast, epifaunal species, which are less tolerant of oxygen depletion (Corliss and Emerson, 1990), are mainly present during warm periods, probably due to lower productivity and higher dissolved oxygen concentrations in bottom waters (Fig. F5A). Important genera represented at Site 1079 include *Bolivina, Bulimina, Cassidulina, Epistominella, Globobulimina,* and *Uvigerina*. The sum of *Bolivina pseudopunctata* and *Bolivina dilatata* (Fig. F5B, F5C) reflects BF/g (and infauna) because of their dominance within the assemblages. Abundances of these two species differ within glacial periods. *B. pseudopunctata* appears to be better correlated with marine C_{org}, represented by the C_{org} record of core GeoB1016, than *B. dilatata,* which tends to covary with the C_{org} record of Site 1079. This suggests that *B. pseudopunctata* prefers labile organic matter, whereas *B. dilatata* does well where influx of terrigenous organic matter dominates the environment. The fact that C_{org} (weight percent) at Site 1079 shows maxima during interglacials could be related to increases in terrestrial nutrient input due to stronger monsoonal flow and precipitation. Alternatively, high interglacial C_{org} (weight percent) values could result from decreased dilution by terrigenous input during sea level highstands. Also, the seasonal pattern of the flux of organic matter to the sea bed seems to have influenced the character of the benthic assemblage. Distributions of some recent deep-sea benthic foraminiferal species are sensitive to seasonal pulses of phytoplankton detritus (Gooday, 1993). Corliss and Silva (1993) showed a rapid seasonal growth response in benthic foraminifers along the California borderlands, probably in response to increased organic matter flux to the seafloor. As for the fossil record, Hermelin and Shimmield (1995) used benthic foraminiferal assemblages recovered from the Arabian Sea to interpret productivity events during the last 150 k.y. Likewise, Thomas et al. (1995) studied benthic foraminifers from the North Atlantic for the last 45 k.y. and interpreted changes in assemblages in terms of abundances of phytodetritus-linked species. The spikiness in the abundance of *B. pseudopunctata* (up to 5000 specimens/g) leads us to believe that this species may be opportunistic

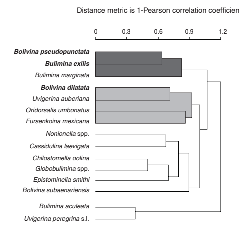
F5. Distribution of benthic foraminifers and organic carbon content, p. 17.



and may respond rapidly to threshold values in environmental conditions. Very few data are available for this species in modern environments.

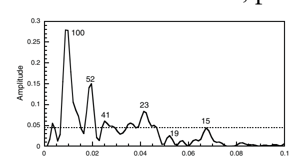
Additional support for this hypothesis comes from the results of the cluster analysis. The dendrogram in Figure F6 shows two major clusters, each represented by one of the two most abundant species. *B. pseudopunctata* associates with *Bulimina exilis* and *Bulimina marginata*. According to previous studies (Caralp, 1984; Jannink et al., 1998), *B. exilis* flourishes under conditions of pulse-like accumulating organic matter of high nutritive quality. On the other hand, species that group with *B. dilatata,* such as *Uvigerina auberiana* and *Fursenkoina mexicana,* may require high but more sustained rather than strongly pulsed flux of organic matter. *Nonionella* spp., *Cassidulina laevigata, Chilostomella oolina, Globobulimina* spp., *Epistominella smithi,* and *Bolivina subaenariensis* are grouped in a cluster, representing the third main contributor to the abundance of benthic foraminifers. These species typically occur in areas with high organic matter input and can tolerate reduced oxygen concentrations (Sen Gupta and Machain-Castillo, 1993; Bernhard et al., 1997). It is worth noting that *Uvigerina peregrina/hispida* and *Bulimina aculeata* are present in samples where *U. auberiana* and *B. marginata* are low, respectively (primarily during interglacials). This pattern could be explained by different ecological preferences related to factors that vary with water depth (e.g., temperature, oxygen, and grain size) and/or resistance to dissolution.

F6. Cluster analysis of the percentages of 15 species, p. 18.



Spectral analyses of the log-transformed BF/g (not presented here) and BFAR records yielded similar results. Variations in the benthic foraminifer abundance and accumulation rates at Site 1079 occur at periods of 100 k.y. (eccentricity) and 23 k.y. (precession), whereas the 41-k.y. cycle (obliquity) is poorly defined (Fig. F7). The distinct 100-k.y. cycle corresponds to the major glacial–interglacial contrast represented by the relatively short record. The predominance of the 23- and 100-k.y. periods over the 41-k.y. period is in accordance with spectral results from SST and productivity records of core GeoB1016 and other eastern South Atlantic cores (Schneider et al., 1996) as well as with previous results from equatorial Atlantic records (e.g., McIntyre et al., 1989). The record of BFAR at Site 1079 also shows strong power at the 52-k.y. period, which may correspond to the difference tone between 41 and 23 k.y., whereas the presence of modest power near 15 k.y. may be related to the sum frequency of the 23- and 41-k.y. cycles, as indicated by Jansen et al. (1996). These authors documented a strong 15-k.y. signal in the record of the Angola-Benguela Front paleopositions during the last 180 k.y. This suggests that migrations of the Angola-Benguela Front may have influenced the productivity fluctuations at Site 1079 and, ultimately, the record of benthic foraminifers. Unfortunately, effects from dissolution on the productivity indices used cannot be entirely excluded; this also may influence the resulting spectrum, making it more complex than it would be for either productivity or dissolution alone.

F7. Spectral analysis on the log-transformed BFAR record, p. 19.



CONCLUSIONS

The agreement between BFAR and other paleoproductivity proxies supports the reliability of BFAR (>150 µm) as an estimator of paleoproductivity at Site 1079. In general, the benthic foraminiferal assemblage is characterized by species preferring a high organic flux and for which oxygen is not a seriously limiting factor (as long as some free oxygen is available). High BFAR values and dominance of infaunal species during glacials reflect low-oxygen bottom-water conditions and high flux of organic matter. The presence of epifauna and decrease of infauna and BFAR during interglacials suggests more oxygenated conditions and lower productivity. Differences in the distribution of *B. pseudopunctata* and *B. dilatata* (the dominant species) could be explained in terms of preferences for amount and/or type of organic flux. Variations in BF/g at Site 1079 occur at 100- and 23-k.y. periodicities. Power in these frequency bands is presumably tied to precessional insolation forcing and the responding trade and monsoon wind systems, as suggested in previous studies from the eastern Angola Basin (Schneider et al., 1995).

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Figure F1. Location of ODP Site 1079 and Bremen University core GeoB1016, surface currents from Schneider et al. (1996) (solid arrow heads = cold, white arrow heads = warm, dotted arrows = subsurface currents), and high productivity areas (dark gray = >150 g C/m²/yr, light gray = 150–100 g C/m²/yr), based on phytoplankton pigment concentrations from color scanning data aboard the CZCS satellite (1978–1986) (NASA data, as published in Berger and Wefer, 1996). BCC = Benguela Coastal Current, BOC = Benguela oceanic current, ABF = Angola Benguela Front, AD = Angola Dome, AC = Angola Current, SECC = South Equatorial Counter Current, SEC = South Equatorial Current, EUC = Equatorial Undercurrent.

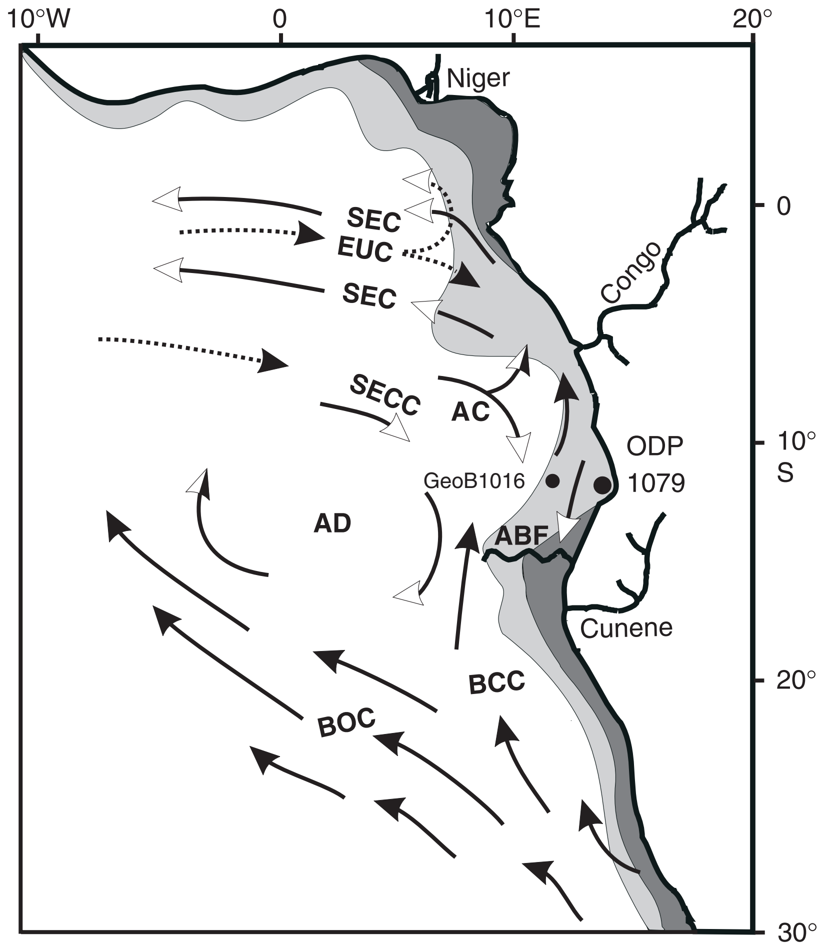

Figure F2. Age scale and productivity estimates for Site 1079. **A.** $\delta^{18}O$ values of *Globobulimina* spp. in Hole 1079A and sedimentation rates (SR) linearly interpolated between age control points. Head bar indicates SPECMAP oxygen isotope stages (Imbrie et al., 1984). **B, C.** Changes in the log-transformed concentration and accumulation rate of benthic (B) and planktonic (C) foraminifers. Shaded intervals = glacial stages. Note the similarity of the foraminiferal concentration and flux records and the fact that glacial periods show higher values than interglacials.

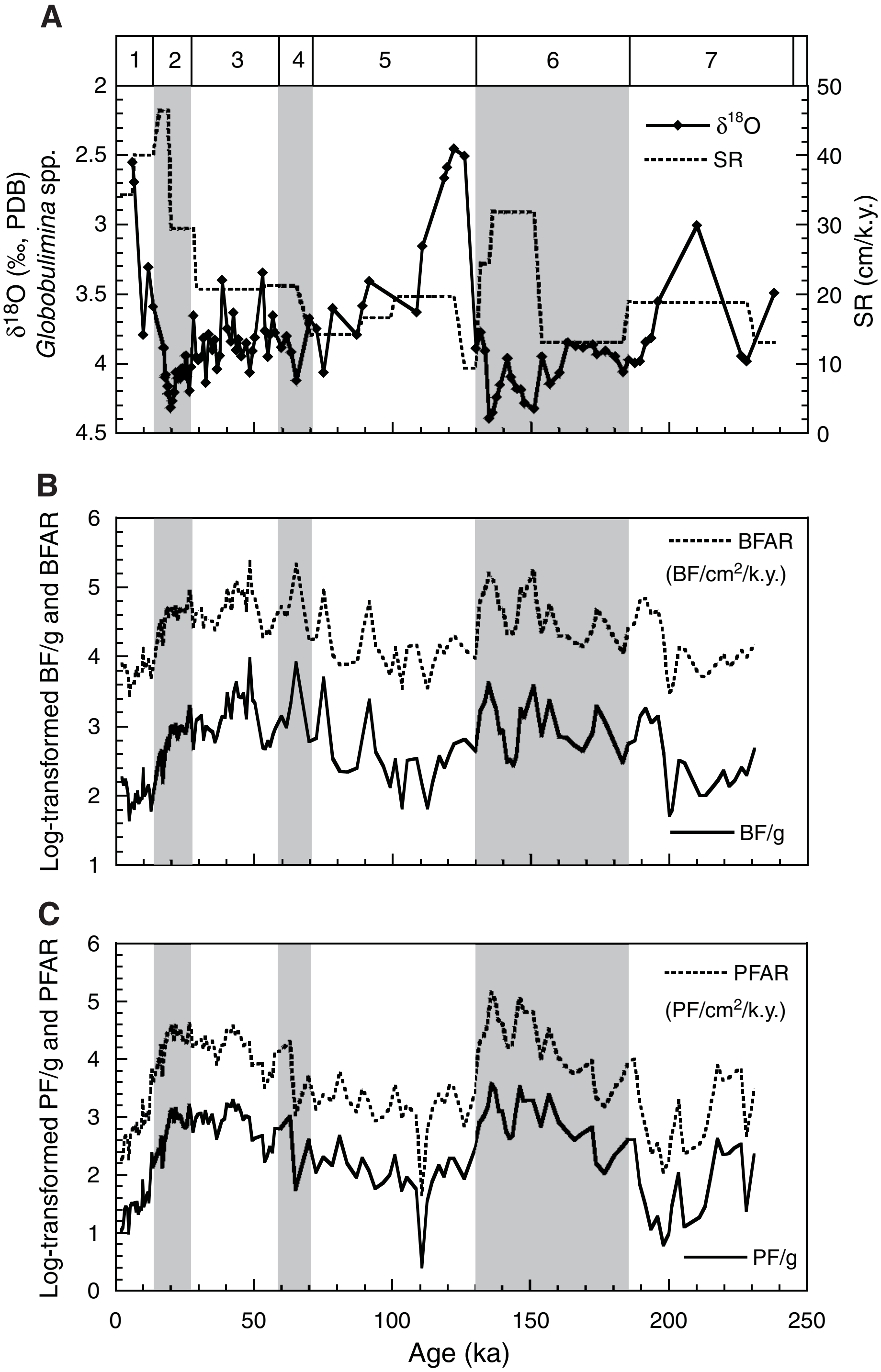

Figure F3. Comparison of preservation-related indices at ODP Hole 1079A. Fields from the bottom up are sand fraction (>63 µm), $CaCO_3$ content, fragmentation (ratio of fragments to whole tests of planktonic foraminifers), and B/P (ratio of benthic to planktonic foraminifers). All values are standardized according to ([x-mean]/standard deviation) and vertically offset (+1) for clarity. Gaps in the fragmentation record are shown where planktonic foraminifers are rare.

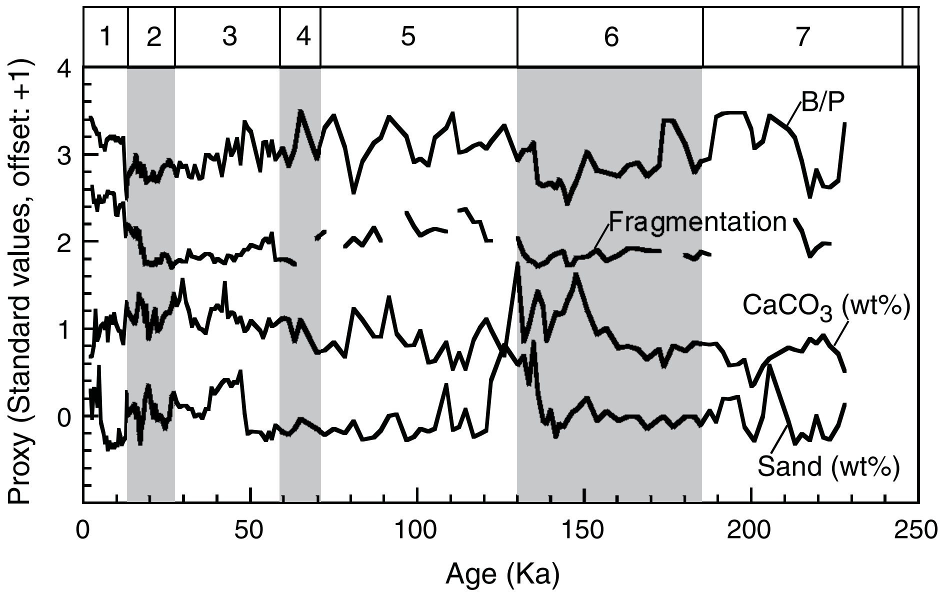

Figure F4. Upwelling indices at Site 1079. **A.** Log-transformed BFAR and *G. bulloides* AR records at ODP Site 1079 and C_{org} in core GeoB1016 (from Müller et al., 1994). **B.** Comparison of *G. bulloides* at Site 1079 with sea-surface temperature (SST) based on alkenone analyses in core GeoB1016 (from Schneider et al., 1995). **C.** BFAR at Site 1079 with the influx of pollen and spores per thousand years and per square centimeter in core GeoB1016 (from Ning and Dupont, 1997).

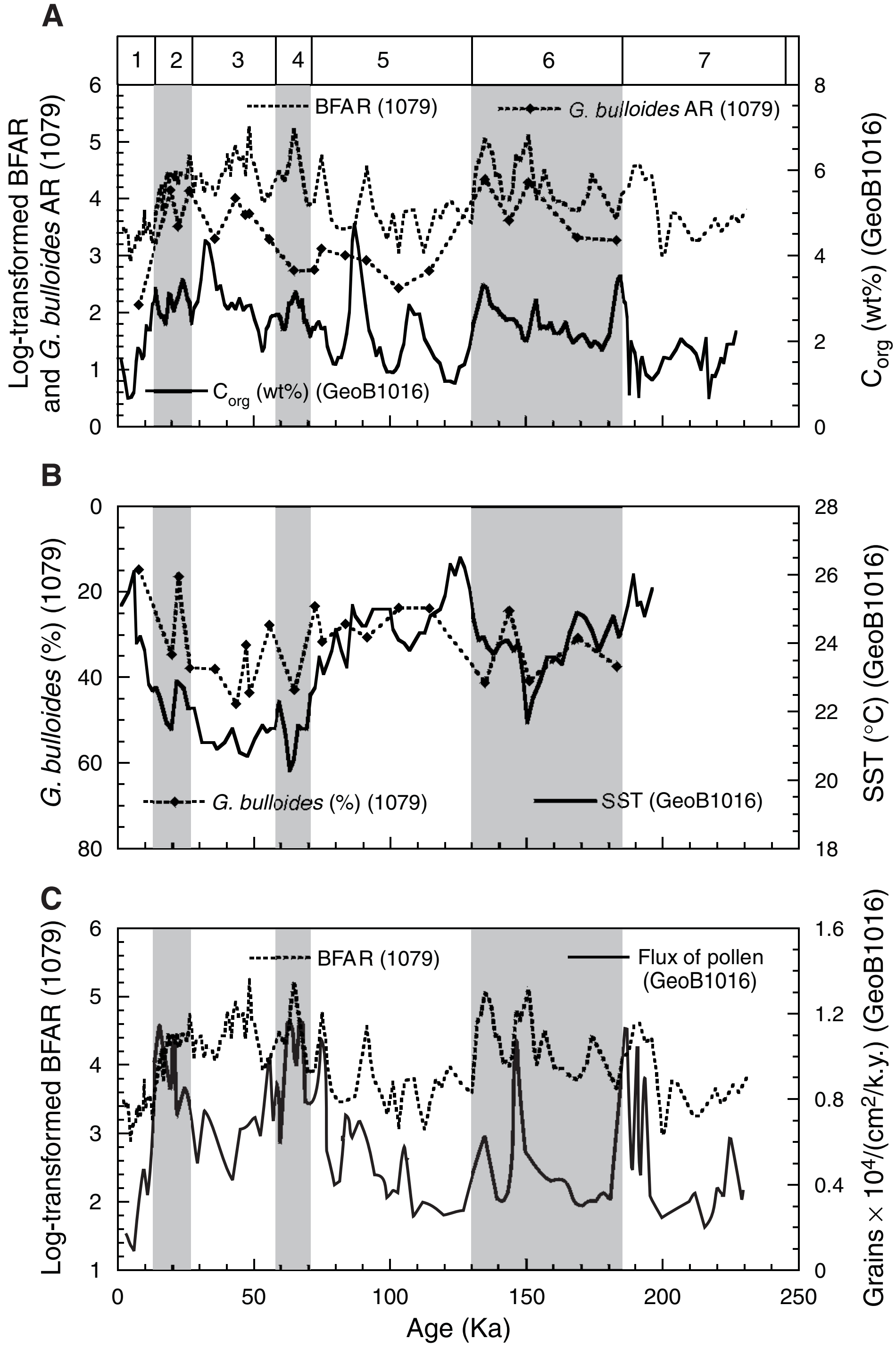

Figure F5. Distribution of benthic foraminifers and organic carbon content. **A.** Relative abundance of epifauna. **B.** Comparison of the percentages of the most abundant species, *Bolivina pseudopunctata,* at Site 1079 with the C_{org} content of core GeoB1016. **C.** Comparison of the percentages of the second most abundant species, *Bolivina,* and C_{org} content at Site 1079.

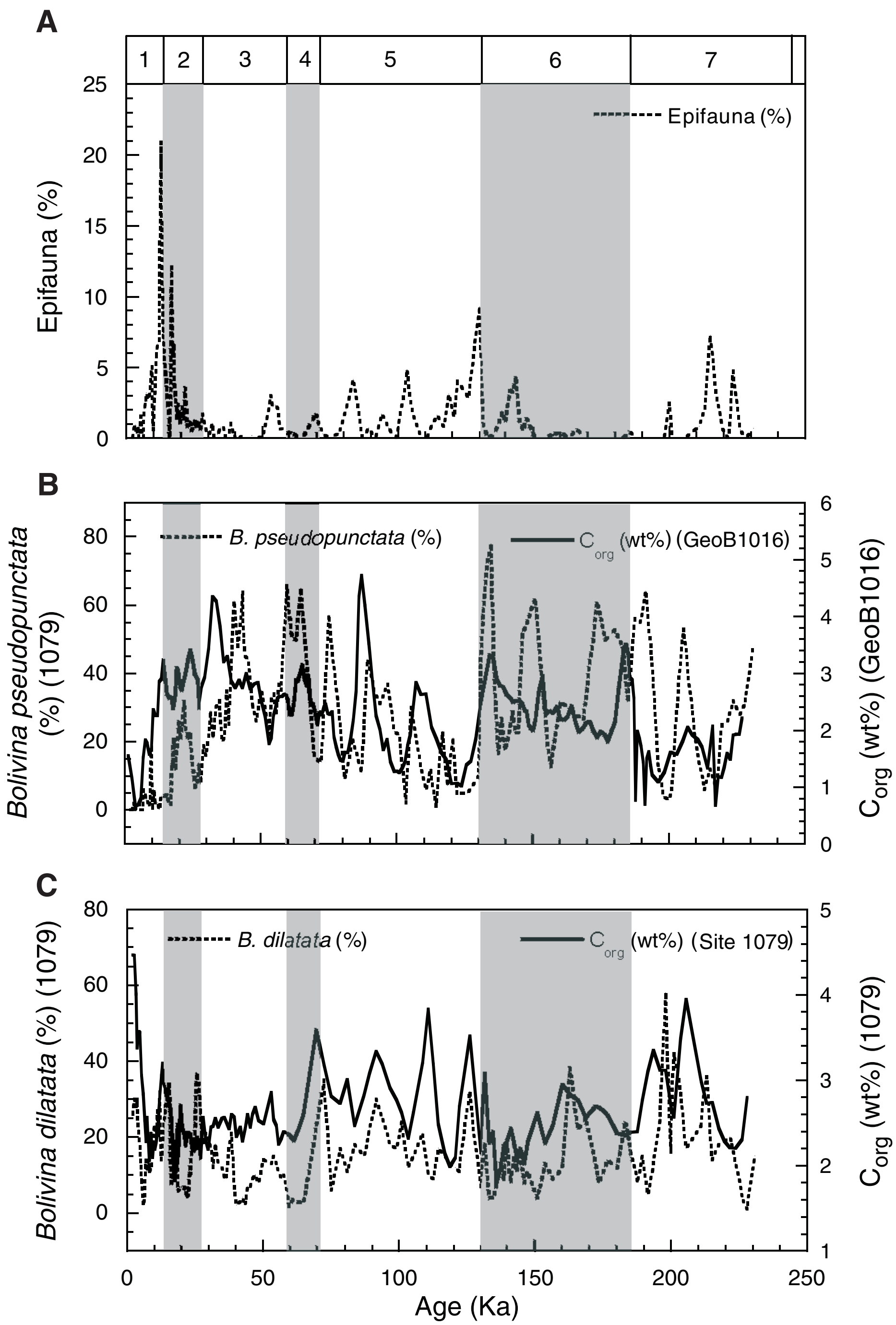

Figure F6. Cluster analysis (average-linkage clustering) of the percentages of fifteen species (with ≥5% in at least five samples) at Site 1079. Shaded areas indicate two major groups, each represented by one of the two dominant species (*Bolivina pseudopunctata* and *Bolivina dilatata*).

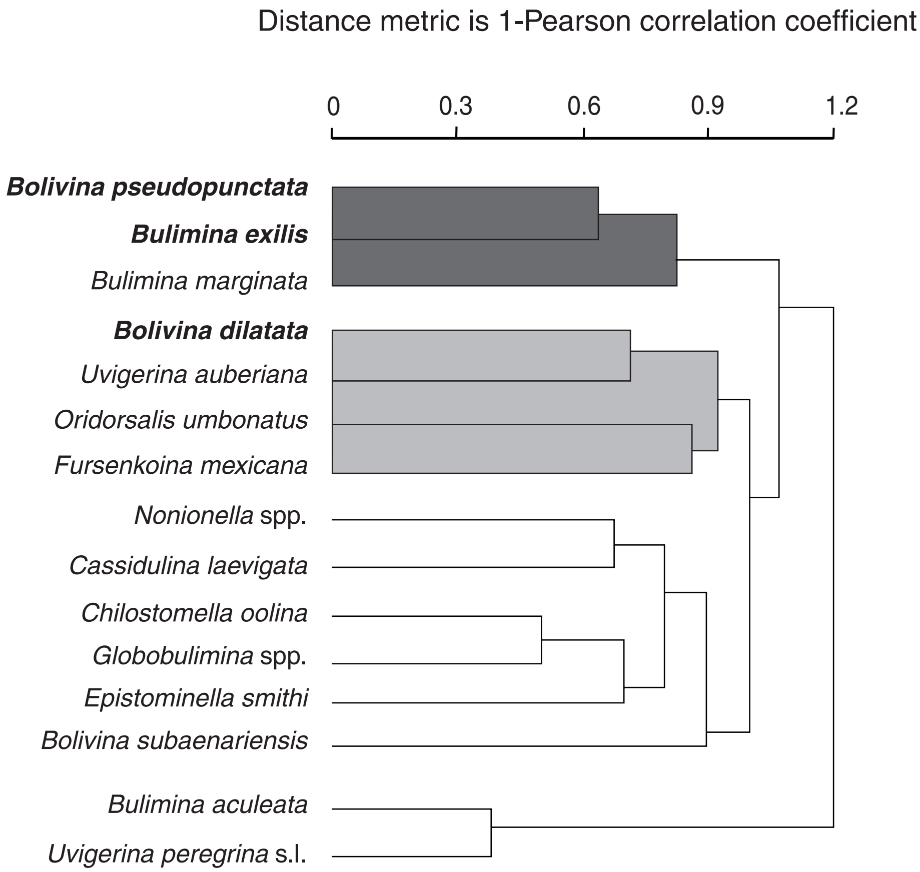

Figure F7. Spectral analysis performed on the log-transformed BFAR record from Site 1079. The dashed line shows the 95% significance level.